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[Title of the Invention] LIGHT EMITTING DEVICE

[What is claimed is]

[Claim 1] A light emitting device comprising a LED chip whose light emitting layer is a gallium nitride compound semiconductor and a phosphor which absorbs at least a part of light emitted by the LED chip to emit light by converting the wavelength, wherein

a main peak of an emission spectrum of the LED chip has an emission wavelength within the range from 400 nm to 530 nm, and

the phosphor contain a first fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce and a second fluorescent material represented by general formula $Re_3Al_5O_{12}$:Ce having a main emission wavelength longer than that of the first fluorescent material, where Re is at least one selected from Y, Gd and La.

[Claim 2] A light emitting device comprising a LED chip whose light emitting layer is a gallium nitride compound semiconductor and a phosphor which absorbs at least a part of light emitted by the LED chip to emit light by converting the wavelength, wherein

a main peak of an emission spectrum of the LED chip has an emission wavelength within the range from 400 nm to 530 nm, and

the phosphor contain a fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce having a main emission wavelength shorter than that of $Y_3Al_5O_{12}$:Ce and a fluorescent material represented by general formula $Re_3Al_5O_{12}$:Ce having a main emission

wavelength longer than that of $Y_3Al_5O_{12}$:Ce, where Re is at least one selected from Y, Gd and La.

[Claim 3] A planar light source comprising a LED chip and a translucent optical guide plate which are optically coupled via a fluorescent material layer containing the phosphor which emits fluorescence when excited by the light emitted by the LED chip, wherein

the light emitting layer of the LED chip is a gallium nitride semiconductor having a main peak of an emission wavelength within the range from 400 nm to 530 nm, and

the phosphor contain a first fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce and a second fluorescent material represented by general formula $Re_3Al_5O_{12}$:Ce having a main emission wavelength longer than that of the first fluorescent material, where Re is at least one selected from Y, Gd and La.

[Claim 4] A planar light source comprising a translucent optical guide plate being provided with the LED chip optically connected to at least part of the side face thereof and on either principal surface of the optical guide plate, a fluorescent member containing a phosphor which emits fluorescence when excited by the light emitted by the LED chip, wherein

the light emitting layer of the LED chip is a gallium nitride semiconductor having a main peak of an emission wavelength within the range from 400 nm to 530 nm, and

the phosphor contain a first fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce and a second fluorescent material represented by general formula $Re_3Al_5O_{12}$:Ce having a main emission wavelength longer than that of the first fluorescent material, where Re is at least one selected from Y, Gd and La.

[Claim 5] A light emitting diode comprising a LED chip placed in a cup of a mount lead, an inner lead electrically connected with the LED chip with a conductive wire, a coating material filling the cup and a molding material covering at least part of the coating material, the LED chip, the conductive wire, the mount lead and the inner lead, wherein

the LED chip is a gallium nitride compound semiconductor and the coating material is translucent resin containing a first fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce and a second fluorescent material represented by general formula $Re_3Al_5O_{12}$:Ce having a main emission wavelength longer than that of the first fluorescent material, where Re is at least one selected from Y, Gd and La.

[Detailed Description of the Invention]

[0001]

[Industrial Utilization Field]

The present invention relates to a light emitting device used in back light source, illuminating switch, signal, display, LED display, indicator, etc. More particularly, it relates to a

light emitting device which emits lights of RGB(red, green, blue) colors with high luminance and high efficiency regardless of the operating environment.

[0002]

[Prior Art]

A light emitting device using a LED chip is compact and emits light of clear color with high efficiency. It is also free from such a trouble as burn-out because it is a semiconductor element. It has an excellent initial drive characteristic and such an advantage as durability to endure vibration and repetitive ON/OFF operations. Thus it has been used in such applications as various indicators and various light sources. Recently light emitting diodes for RGB (red, green and blue) colors having ultra-high luminance and high efficiency have been developed. Accordingly, planar light sources for full color, which can be used in a liquid crystal back-light, using the three primary colors of RGB have been greatly advancing by making most of the advantages such as low power consumption, long life and light weight.

[0003]

The LED chip can emit light of various wavelengths ranging from ultra violet to infrared, depending on the semiconductor material and conditions to form a light emitting layer to be used. It also has favorable emission spectrum to generate monochromatic light.

[0004]

Although because the light emitting diode has favorable emission spectrum to generate monochromatic light, making a light source for white light requires it to arrange the LED chips which are capable of emitting light of RGB colors closely to each other while diffusing and mixing the light emitted by them. Although these light emitting diodes are effective as light emitting devices for emitting various colors freely, a set of red green and blue light emitting diodes or a set of blue-green and yellow light emitting diodes must be used even when generating white light only. A LED chip is a semiconductor and still includes considerable variations in the color tone and luminance. The LED chip which can emit lights of RGB colors with high luminance has not been yet made from the same semiconductor material. In case the LED chips which are semiconductor light emitting component are made from different materials, different LED chips require different drive voltages which must be supplied from different power sources provided separately. Therefore, white light must be generated by adjusting the current for each semiconductor. Similarly, color tone is subject to variation due to the difference in temperature characteristics and chronological changes, because the LED chips are semiconductor light emitting components. Further, uneven color may result unless the light rays emitted by the LED chips are mixed evenly.

[0005]

Thus, the present applicant previously developed a light

emitting diode which converts the color of light emitted by a LED chip by means of a fluorescent material and a planar light source disclosed in Japanese Patent Kokai Nos. 5-152609, 7-176794 and 8-8614. By using the light emitting diode and the planar light source, light of other colors such as white color can be emitted by using a LED chip of one type.

Specifically, a LED chip capable of emitting blue light is connected to one end of a transparent optical guide plate and light emitted by the LED chip is converted by a layer containing a fluorescent material provided on the optical guide plate into green and red light, thereby to produce light of white color. These devices can be used as light emitting devices which emit light for an extended period of time with a sufficient luminance, even when used as light emitting device capable of emitting light of white color having RGB light components.

[0006]

[Problems to be solved by the Invention]

There are various fluorescent materials such as fluorescent dye, fluorescent pigment and organic or inorganic compounds which are excited by light emitted by a LED chip. Excitation wavelengths and emission wavelengths of fluorescent materials also range widely. Also there are fluorescent materials which convert light of shorter wavelength emitted by a light emitting element into light of longer wavelength and those which convert light of longer wavelength emitted by a light emitting

component into light of shorter wavelength.

[0007]

However, efficiency of conversion of long-wavelength light into short-wavelength light is extremely low and is not practical. When a light emitting device is used in outdoor environment such as under direct sunlight, or when a fluorescent material is located in the vicinity of the LED chip, the fluorescent material remains to be irradiated by high-energy radiations such as ultra violet ray of strong intensities for a long period of time. Especially when a LED chip as a light emitting component is made by using a semiconductor having a high energy band gap to improve the conversion efficiency of the fluorescent material and reduce the quantity of the fluorescent material consumed, light energy inevitably increases even though the light emitted by the LED chip falls within visible light range. Therefore, the fluorescent material itself is subject to deterioration due to the synergistic effect with the extraneous light such as sun light.

[0008]

There are such cases as the color tone changes as the fluorescent material deteriorates or the fluorescent material is blackened resulting in lowered efficiency of extracting light. Similarly, the fluorescent material is exposed to a high temperature such as rising temperature of the LED chip and from the external environment. Further, although a light emitting device is usually sealed in a plastic casing, it is impossible to completely

prevent the entry of moisture from the outside or to completely remove moisture which was contained during production. In the case of some fluorescent materials, such moisture accelerates the deterioration of the fluorescent material due to the high-energy radiation or heat transmitted from the light emitting component. When it comes to an organic dye of ionic property, direct current electric field in the vicinity of the chip may cause electrophoresis, resulting in a change in the color tone. Therefore, an object of the present invention is to solve the problems described above and provide a light emitting device which is subject only to extremely low degrees of deterioration in light emission efficiency and color shift over a long period of time even when used outdoors, and is capable of emitting light of RGB colors with a high luminance.

[0009]

[Means for Solving the Problems]

The he present invention provides a light emitting device comprising a LED chip whose light emitting layer is a gallium nitride compound semiconductor and a phosphor which absorbs at least a part of light emitted by the LED chip to emit light by converting the wavelength, wherein a main peak of an emission spectrum of the LED chip has an emission wavelength within the range from 400 nm to 530 nm, and the phosphor contain a first fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce and a second fluorescent material represented by general formula $Re_3Al_5O_{12}$:Ce having a main emission wavelength longer than that of the first

fluorescent material, where Re is at least one selected from Y, Gd and La.

[0010]

The present invention also provides a light emitting device comprising a LED chip whose light emitting layer is a gallium nitride compound semiconductor and a phosphor which absorbs at least a part of light emitted by the LED chip to emit light by converting the wavelength, wherein a main peak of an emission spectrum of the LED chip has an emission wavelength within the range from 400 nm to 530 nm, and the phosphor contain a fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce having a main emission wavelength shorter than that of $Y_3Al_5O_{12}$:Ce and a fluorescent material represented by general formula $Re_3Al_5O_{12}$:Ce having a main emission wavelength longer than that of $Y_3Al_5O_{12}$:Ce, where Re is at least one selected from Y, Gd and La.

[0011]

Further, the present invention provides a planar light source comprising a LED chip and a translucent optical guide plate which are optically coupled via a fluorescent material layer containing the phosphor which emits fluorescence when excited by the light emitted by the LED chip, wherein the light emitting layer of the LED chip is a gallium nitride compound semiconductor having a main peak of an emission wavelength within the range from 400 nm to 530 nm, and the phosphor contain a first fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce and a second

fluorescent material represented by general formula $Re_3Al_5O_{12}:Ce$ having a main emission wavelength longer than that of the first fluorescent material, where Re is at least one selected from Y, Gd and La.

[0012]

Further the present invention provides a planar light source comprising a translucent optical guide plate being provided with the LED chip optically connected to at least part of the side face thereof and on either principal surface of the optical guide plate, a fluorescent member containing a phosphor which emits fluorescence when excited by the light emitted by the LED chip, wherein the light emitting layer of the LED chip is a gallium nitride compound semiconductor having a main peak of an emission wavelength within the range from 400 nm to 530 nm, and the phosphor contain a first fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}:Ce$ and a second fluorescent material represented by general formula $Re_3Al_5O_{12}:Ce$ having a main emission wavelength longer than that of the first fluorescent material, where Re is at least one selected from Y, Gd and La.

[0013]

Also, the present invention provides a light emitting diode comprising a LED chip placed in a cup of a mount lead, an inner lead electrically connected with the LED chip with a conductive wire, a coating material filling the cup and a molding material covering at least part of the coating material, the LED chip, the conductive

wire, the mount lead and the inner lead, wherein the LED chip is a gallium nitride compound semiconductor and the coating material is translucent resin containing a first fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce and a second fluorescent material represented by general formula $Re_3Al_5O_{12}$:Ce having a main emission wavelength longer than that of the first fluorescent material, where Re is at least one selected from Y, Gd and La.

[0014]

[Mode for carrying out the Invention]

The present inventors have found, as a result of various experiments, that it is made possible to prevent the decrease in emission efficiency and color shift through operation with a high luminance over a long period of time by selecting a particular semiconductor and a fluorescent material in a light emitting diode which uses a phosphor to convert the color of light emitted by a LED chip having a relatively high radiation energy in visible region into green and red, and have achieved the present invention.

[0015]

The phosphor used in the light emitting diode must satisfy the following requirements:

1. Excellent resistance against light, particularly durability to endure direct sun light in which lights with various high energy are radiated for a long period. And durability to endure light of a radiation illuminance as high as Ee=3Wcm^{-2} and more because

the fluorescent material is exposed to intense radiation from a tiny region such as a semiconductor light emitting component when used as a light emitting diode.

2. Capability to emit light in blue region, not ultra violet, because mixing of colors with the light emitting elements is used.

3. Capability to emit light from green to red regions with high luminance in consideration of mixing with blue light.

4. Good temperature characteristic suitable for location in the outdoor and in the vicinity of the light emitting component.

5. Capability to continuously change the color tone in terms of the proportion of composition or ratio of mixing a plurality of fluorescent materials.

6. Weatherability for the operating environment of the light emitting diode.

[0016]

As materials that satisfy the above requirements, the present invention uses a gallium nitride compound semiconductor element having high-energy band gap in the light emitting layer as the light emitting component, and a $Y_3(Al,Ga)_5O_{12}$:Ce fluorescent material and a $Re_3(Al,Ga)_5O_{12}$:Ce fluorescent material, where Re is at least one selected from Y, Gd and La, as the phosphor. This makes it possible to make a light emitting component which experiences color shift of emitted light and a decrease in luminance of the

emitted light, both of very low degrees, even when irradiated with high-energy radiation in the visible light region emitted by the light emitting component in the vicinity thereof over a long period of time or used outdoors, and emits light of RGB colors with high luminance.

[0017]

As one embodiment of the light emitting device, a chip type LED is shown in Fig. 1. A LED chip employing gallium nitrate semiconductor is fixed in the casing of the chip type LED by means of epoxy resin or the like. Electrodes of the LED chip and electrodes 105 provided on the casing are electrically connected by means of gold wires 103 which are conductive wires. The LED chip made by mixing and dispersing $Y_3(Al,Ga)_5O_{12}$:Ce as phosphor of green color and $RE_3Al_5O_{12}$:Ce (where Re is at least one selected from Y, Gd and La) as phosphor of red color in an acrylic resin, and the conductive wires are protected from extraneous stresses by a molding material 101 which is uniformly applied and cured. The LED chip is caused to emit light by supplying electric power to the light emitting device. By mixing blue light emitted by the LED chip and light emitted by two or more kinds of phosphor capable of emitting light of high luminance when excited by the light emitted by the LED chip, the light emitting diode can emit light of white color. Constituents of the present invention will now be described below.

[0018]

(phosphor)

The phosphor used in this invention refers to a phosphor which emits light when excited by visible light or ultra violet light emitted by the semiconductor light emitting layer. The phosphor contains a fluorescent material which can emit light of red color with high luminance and a fluorescent material which can emit light of green color with hight luminance. Specifically, the phosphor may include $RE_3Al_5O_{12}$:Ce (where Re is at least one selected from Y, Gd and La) fluorescent material which can emit light of red color and $Y_3(Al,Ga)_5O_{12}$:Ce fluorescent material which can emit light of green color. Desired white color can be produced by mixing light of blue color emitted by a LED chip employing a gallium nitride compound semiconductor, light of green color and light of red color emitted by the phosphor with yellow body color. In the light emitting device, in order to achieve this color mixture, it is preferable that the phosphor in the form of powder or bulk be contained in resins or glass and such a material which includes phosphor can be used in various forms such as dot-shaped construction and a layer formed thin enough to transmit light from the LED chip. Various colors containing white and incandescent lamp color can be produced by adjusting the mix proportion of phosphor and resin and the amount of coating or filling material and selecting the wavelength of light emitted by the light emitting component.

[0019]

The distribution can be adjusted by changing the material which includes the phosphor, forming temperature and viscosity and

the shape and particle size distribution of the phosphor. Therefore, desired concentration of the fluorescent material can be selected depending on the operating conditions.

[0020]

By using the phosphor of the present invention, the light emitting device can be given enough light resistance for high-efficient operation even when arranged adjacent to or in the vicinity of a LED chip of radiation illuminance (Ee) in a range from 3 Wcm^{-2} up to 10 Wcm^{-2}.

[0021]

The first phosphor capable of emitting green light used in the present invention has garnet structure, and is therefore resistant to heat, light and moisture, thereby to be capable of absorbing excitation light having a peak at a wavelength near 450 nm as indicated by the solid line in Fig. 4(A). It emits light of broad spectrum having a peak near 510 nm tailing out to 750 nm as indicated by the solid line in Fig. 4(B). The second phosphor capable of emitting red light, too, has garnet structure and is therefore resistant to heat, light and moisture, and is capable of absorbing excitation light having a peak near 450 nm as indicated by the wavy line in Fig. 4(A). It also emits light of broad spectrum having a peak near 600 nm tailing out to 750 nm as indicated by the wavy line in Fig. 4(B).

[0022]

Wavelength of the emitted light is shifted to a shorter

wavelength by substituting part of Al, among the constituents of the YAG fluorescent material having garnet structure, with Ga, and the wavelength of the emitted light can be shifted to a longer wavelength by substituting part of Y with Gd and/or La. Proportion of substituting Al with Ga is preferably from Ga:Al=1:1 to 4:6 in consideration of the light emitting efficiency and the wavelength of emission. Similarly, proportion of substituting Y with Gd and/or La is preferably from Y:Gd and/or La=9:1 to 1:9, or more preferably from Y:Gd and/or La=1:4 to 2:3. Substitution of less than 60% results in an increase of green component and a decrease of red component. Substitution of 80% or greater part, on the other hand, increases red component but decreases the luminance steeply.

[0023]

Material for making such a phosphor is made by using oxides of Y, Gd, Ce, La, Al and Ga or compounds which can be easily converted into these oxides at high temperatures, and sufficiently mixing these materials in stoichiometrical proportions. Otherwise, the mixture material is obtained by dissolving rare earth elements Y, Gd, Ce, and La in stoichiometrical proportions in an acid, coprecipitating the solution with oxalic acid and firing the coprecipitate to obtain an oxide of the coprecipitate, which is then mixed with aluminum oxide and gallium oxide. This mixture is mixed with an appropriate quantity of a fluoride such as ammonium fluoride used as a flux, and fired in a crucible at a temperature from 1350 to 1450 °C in air for 2 to 5 hours. Then the fired material is ground

by ball mill in water, washed, separated, dried and sieved thereby to obtain the desired material.

[0024]

(LED chips 102, 202, 302)

As the light emitting element used in the present invention, a nitride compound semiconductor capable of efficiently exciting the first and the second phosphors may be used. The LED chip which is the light emitting component can be made by forming light emitting layer of semiconductor such as InGaN on a substrate in the MOCVD process. The semiconductor structure may be homostructure, heterostructure or double-heterostructure which have MIS junction, PIN junction or PN junction. Various wavelengths of emitted light can be selected depending on the material of the semiconductor layer material and the crystallinity thereof. It may also be made in a single quantum well structure or multiple quantum well structure where a semiconductor active layer is formed in a thin film where quantum effect can occur.

[0025]

When a gallium nitride compound semiconductor is used, sapphire, spinnel, SiC, Si, ZnO or the like is used as the semiconductor substrate. Use of sapphire substrate is preferable in order to form gallium nitride of good crystalinity. A buffer layer of GaN, AlN, etc. is formed on the sapphire substrate, and gallium nitride semiconductor having PN junction is formed thereon. The gallium nitride semiconductor has N type conductivity under

the condition of not doped with any impurity. In order to form an N type gallium nitride semiconductor having desired properties such as improved light emission efficiency, it is preferably doped with N type dopant such as Si, Ge, Se, Te, and C. In order to form a P type gallium nitride semiconductor, on the other hand, it is preferably doped with P type dopant such as Zn, Mg, Be, Ca, Sr and Ba. Because it is difficult to turn a gallium nitride compound semiconductor to P type simply by doping a P type dopant, it is preferable to anneal the gallium nitride compound semiconductor doped with P type dopant in such process as irradiation with low-speed electron beam, plasma irradiation, etc., thereby to turn it to P type. After exposing the surfaces of P type and N type semiconductor layers by etching or other process, electrodes of the desired shapes are formed on the semiconductor layers by sputtering or vapor deposition.

[0026]

Then the semiconductor wafer which has been formed is cut into pieces by means of a dicing saw which has a rotating blade having diamond cutting edge, or separated by an external force after cutting grooves (half-cut) which have width greater than the blade edge width. Or otherwise, the wafer is cut into chips by scribing grid pattern of extremely fine lines on the semiconductor wafer by means of a scriber having a diamond stylus which makes straight reciprocal movement. Thus the LED chips of gallium nitride compound semiconductor can be made.

[0027]

In order to emit white light with the light emitting diode of the present invention, wavelength of main light emitted by the light emitting component is preferably from 400 nm to 530 nm inclusive in consideration of the mixing color with the phosphor, and more preferably from 420 nm to 490 nm inclusive. It is further more preferable that the wavelength be from 450 nm to 475 nm inclusive, so as to increase the emission efficiency of the LED chip and the phosphor, respectively.

[0028]

(Conductive wires 103, 303)

The conductive wires should have good electric conductivity, good thermal conductivity and good mechanical connection with the electrodes of the LED chips 102, 302. Thermal conductivity is preferably 0.01 cal/cm^2/cm/°C or higher, and more preferably 0.5 cal/cm2/cm/°C or higher. For workability and other reasons, the diameter of the conductive wire is preferably from Φ10 μm to Φ45 μm inclusive. The conductive wire may specifically be a metal such as gold, silver, platinum and aluminum or an alloy thereof. Such a conductive wire can be easily connected to the electrodes of the LED chips, the inner lead 306 and the mount lead 305 by means of a wire bonding device.

[0029]

(Mount lead 305)

The mount lead 305 is used for mounting of the LED chip

302, and suffices to have a size enough to load the LED chip 302 with a die bonding equipment or the like. In case a plurality of LED chips are installed and the mount lead is used as common electrode of the LED chips, sufficient electric conductivity and good connecting characteristic with the bonding wires and the like are required. When the LED chip is installed in the cup of the mount lead and the cup is filled with the fluorescent material, erroneous illumination due to light from other light emitting diode mounted nearby can be prevented.

[0030]

Bonding of the LED chip 302 and the mount lead 305 with the cup can be achieved by means of a thermoplastic resin. Specifically, epoxy resin, acrylic resin and imide resin can be used. When bonding a face-down LED chip and the mount lead and, at the same time, electrically connecting them, Ag paste, carbon paste, metallic bump or the like can be used.

[0031]

Further, in order to improve the efficiency of light utilization of the light emitting diode, surface of the mount lead whereon the LED chip 302 is mounted may be mirror-polished to give reflecting function to the surface. In this case, the surface roughness is preferably from 0.1S to 0.8S inclusive. Electric resistance of the mount lead is preferably within 300 $\mu\Omega$-cm and more preferably within 3 $\mu\Omega$ -cm.

[0032]

When mounting a plurality of LED chips on the mount lead, the LED chips generate significant amount of heat and therefore high thermal conductivity is required. Specifically, the thermal conductivity is preferably 0.01 cal/cm^2/cm/°C or higher, and more preferably 0.5 cal/cm2/cm/°C or higher. Materials which satisfy these requirements include steel, copper, copper-clad steel, copper-clad tin and metallized ceramics.

[0033]

(Inner lead 306)

The inner lead 306 provides connection between the LED chip mounted on the mount lead 305 and the conductive wire. When mounting a plurality of LED chips 302 on the mount lead, it is necessary to employ such a construction that the conductive wires can be arranged so as not to touch each other.

[0034]

Specifically, contact of the conductive wires with each other which connect the inner leads that are more distant from the mount lead can be prevented by increasing the area of the end face where the inner lead 306 is wire-bonded as the distance from the mount lead increases.

[0035]

Surface roughness of the end face connecting with the conductive wire is preferably from 1.6S to 10S inclusive in consideration of close contact. In order to form the tip of the inner lead in a desired shape, the shape may be formed by punching

the lead frame with a die in advance, or by grinding off a part of inner leads at the top after forming all inner leads. Further, after forming by punching the inner leads, desired end face area and height can be formed simultaneously by applying pressure in the direction of end face.

[0036]

The inner lead is required to have good connectivity with the bonding wires which are conductive wires and good electrical conductivity. Specifically, the electric resistance is preferably within 300 $\mu\Omega$-cm and more preferably within 3 $\mu\Omega$-cm. Materials which satisfy these requirements include iron, copper, copper containing iron, copper containing tin, copper-, gold- or silver-plated aluminum, iron or copper.

[0037]

(Coating material 301)

The coating material 301 used in the present invention is provided in the cup of the mount lead 305 in addition to the molding material 304, and includes the phosphor which converts the light emitted by the LED chip 302. As the coating material, transparent materials of excellent weatherability such as epoxy resin, urea resin and silicon and glass are preferably employed. A dispersant may be used together with the phosphor. As the dispersant, barium titanate, titanium oxide, aluminum oxide, silicon dioxide and the like are preferably used.

[0038]

(Molding material 101, 210, 304)

The molding may be provided in order to protect the LED, the conductive wire and the coating material which includes phosphor from external disturbance, depending on the application of the light emitting device. The molding material can be generally made of a resin or glass. The angle of view can be increased by containing the phosphor. And also, the angle of view can be further increased by adding a dispersant, thereby making the directivity of the emission from the LED chip dull.

[0039]

Further, the molding material may be formed in a desired shape having the function of lens to focus or diffuse the light emitted by the LED chip. Therefore, the molding material may be made in a structure of multiple layers laminated. Specifically, it may be a convex lens or a concave lens, and may have an elliptic shape when viewed in the direction of optical axis, or a combination of these.

[0040]

As the molding material, transparent materials of excellent weatherability such as epoxy resin, urea resin and silicon resin, and glass having a low melting point are preferably employed. As the dispersant, barium titanate, titanium oxide, aluminum oxide, silicon dioxide and the like are preferably used. The phosphor may be contained either in the molding material or in the coating material and other part. Or otherwise, the coating may be of other

materials such as a resin containing phosphor and the molding material may be glass. In this case, such a light emitting diode can be made that is suited to mass production and is less affected by moisture. The molding and the coating may also be made of the same material in consideration of the refractive index.

[0041]

(Planar light source)

A planar light source which is one of light emitting devices of the present invention can be made either by turning white light into planar light by means of an optical guide plate when emitting white light as shown in Fig. 2(A), or by converting blue light emitted by the LED chip which emits planar light into white light as shown in Fig. 2(B).

[0042]

When turning white light into planar light by means of an optical guide plate, it can be achieved either by such a construction that a light emitting diode 202 capable of emitting blue light and an optical guide plate 204 are arranged interposing a color conversion layer 201 which includes phosphor, or by such a construction that the light emitting diode 202 having nitride semiconductor light emitting component which includes phosphor to be capable of emitting blue light and the optical guide plate 204 are optically coupled in a molding material 210 or the like.

[0043]

When converting blue light emitted by the LED chip 202

which emits planar light into white light, the light emitting diode 202, which includes a nitride semiconductor in the light emitting layer and is capable of emitting blue light, and the optical guide plate 204 are optically coupled and then the phosphor is contained in a diffusion sheet 206 on the optical guide plate 204, or otherwise applied on the diffusion sheet together with a binder resin to form a sheet. Further, such a construction may also be employed as a binder containing phosphor is formed into dot-shape on the optical guide plate.

[0044]

Specifically, the LED chip is fixed in a metal substrate 203 or the like having inverted C shape whereon an insulation layer and a conductive pattern are formed. After electrically connecting the LED chip and the conductive pattern, epoxy resin is applied onto the substrate whereon the LED chip 202 is mounted, thereby to optically couple with an end face of the acrylic optical guide plate 204. Placed on the principal light emitting plane of the optical guide plate 204 is a sheet 201 made by applying a mixture of phosphor and epoxy resin uniformly on a diffusion sheet. The diffusion sheet 206 comprises a layer made by applying epoxy resin containing particles of aluminum oxide, silicon dioxide, titanium oxide or barium titanate as diffusion agent in a base of acrylic resin and a layer containing phosphor.

[0045]

It is preferable that a reflector film 207 containing

a white diffusion agent be arranged on one principal plane of the optical guide plate for the purpose of preventing fluorescence. Similarly, a reflector 205 is provided on the entire surface on the back of the optical guide plate 204 and on one end face where the light emitting diode is not provided, in order to improve the light emission efficiency. With this configuration, a planar light source can be obtained which generates enough luminance even when used as the back light of LCD. Application to a liquid crystal display can be achieved by arranging a polarizer plate on the principal plane of the optical guide plate via liquid crystal injected between glass substrates whereon a translucent conductive pattern not shown in the drawing is formed. Examples of the present invention will be described below. It goes without saying that the present invention is not limited to the Examples.

[0046]

[Examples]

(Example 1)

GaInN semiconductor having emission peak at 450 nm is used as a light emitting component. A LED chip is made by flowing TMG (trimethyl gallium) gas, TMA (trimethyl aluminum) gas, nitrogen gas and dopant gas together with a carrier gas on a cleaned sapphire substrate and forming a gallium nitride compound semiconductor layer in MOCVD process. A gallium nitride semiconductor layer having N type conductivity and a gallium nitride semiconductor layer having P type conductivity are formed by switching SiH_4 and Cp_2Mg

as dopant gas, thereby forming a PN junction. (The P type semiconductor is annealed at a temperature of 400 °C or above after forming the film.)

[0047]

After exposing the surfaces of P type and N type semiconductor layers by etching, electrodes are formed by sputtering. After scribing the semiconductor wafer which has been made as described above, LED chips are made as light emitting components by dividing the wafer with external force.

[0048]

The LED chip is mounted on a mount lead which has a cup at the tip of a silver-plated copper lead frame, by die bonding with epoxy resin. Electrodes of the LED chip, the mount lead and inner lead are electrically connected by wire boding with gold wires.

[0049]

The lead frame with the LED chip attached thereon is placed in a bullet-shaped die and sealed with translucent epoxy resin for molding, which is then cured at 150 °C for 5 hours, thereby to form a blue light emitting diode. The blue light emitting diode is connected to one end face of an acrylic optical guide plate which is polished on all end faces. On one surface and side face of the acrylic plate, screen printing is applied by using barium titanate dispersed in an acrylic binder as white color reflector, which is then cured.

[0050]

On the other hand, phosphors of green and red colors are made by dissolving rare earth elements of Y, Gd, Ce and La in an acid in stoichiometrical proportions, and coprecipitating the solution with oxalic acid. Oxide of the coprecipitate obtained by firing this material is mixed with aluminum oxide and gallium oxide, thereby to obtain respective mixture materials. The mixture is then mixed with ammonium fluoride used as a flux, and fired in a crucible at a temperature of 1400 °C in air for 3 hours. Then the fired material is ground by a ball mill in water, washed, separated, dried and sieved thereby to obtain the desired material.

[0051]

120 Parts by weight of the first fluorescent meterial having a composition of $Y_3(Al_{0.6}Ga_{0.4})_5O_{12}$:Ce and capable of emitting green light, 100 parts by weight of the second fluorescent material having a composition of $(Y_{0.4}Gd_{0.6})_3Al_5O_{12}$:Ce and capable of emitting red light, prepared in a process similar to that for the first fluorescent material, are sufficiently mixed with 100 parts by weight of epoxy resin, to form a slurry. The slurry is applied uniformly onto an acrylic layer of thickness of 0.5 mm by means of a multi-coater and then dried to form a fluorescent material layer used as a color converting layer having a thickness of about 30 μm. The fluorescent material layer is cut into the same size as that of the principal light emitting plane of the optical guide plate, and arranged on the optical guide plate thereby to form the light emitting device. Measurements of chromaticity point, color

temperature and color rendering index of the light emitting device gave values of (0.29, 0.34) for chromaticity point (x, y), color temperature of 7000 K and 80 for Ra (color rendering index) which are approximate to 3-waveform fluorescent lamp. Light emitting efficiency of 12 m/W comparable to that of an incandescent lamp was obtained. Further in weatherability tests under conditions of energization with a current of 60 mA at room temperature, 20 mA at room temperature and 20 mA at 60 °C with 90% RH, no change due to the fluorescent material was observed.

[0052]

(Comparative Example 1)

According to the same manner as that described in Example 1 except for mixing the same quantities of a green organic fluorescent pigment (FA-001, manufactured by Synleuch Chemical Co.) and a red organic fluorescent pigment (FA-005, manufactured by Synleuch Chemial Co.) which are perylene-derivatives for the first and the second phosphor, the formation of a light emitting diode and weatherability test were conducted. Chromaticity coordinates of the light emitting diode thus formed were (x, y) = (0.34, 0.35). The weatherability test was conducted by irradiating with ultraviolet ray generated by carbon arc for 200 hours, representing equivalent irradiation of sun light over a period of one year, while measuring the luminance retaining ratio and color tone at various times during the test period. In a reliability test, the LED chip was energized to emit light at a constant temperature of 70 °C while

measuring the luminance and color tone at different times. The results are shown in Fig. 6 and Fig. 7, together with Example 1.

[0053]

(Example 2)

GaInN semiconductor having emission peak at 450 nm is used as a light emitting component. A LED chip is made by flowing TMG (trimethyl gallium) gas, TMA (trimethyl aluminum) gas, nitrogen gas and dopant gas together with a carrier gas on a cleaned sapphire substrate and forming a gallium nitride compound semiconductor layer in MOCVD process. A gallium nitride semiconductor layer having N type conductivity and a gallium nitride semiconductor layer having P type conductivity are formed by switching SiH_4 and Cp_2Mg as dopant gas, thereby forming a PN junction. (The P type semiconductor is annealed at a temperature of 400 °C or above after forming the film.)

[0054]

After exposing the surfaces of P type and N type semiconductor layers by etching, electrodes are formed by sputtering. After scribing the semiconductor wafer which has been made as described above, LED chips are made as light emitting components by dividing the wafer with external force.

[0055]

The LED chip is mounted on a mount lead which has a cup at the tip of a silver-plated copper lead frame, by die bonding with epoxy resin. Electrodes of the LED chip, the mount lead and inner

lead are electrically connected by wire boding with gold wires.

[0056]

On the other hand, phosphors of green and red colors are made by dissolving rare earth elements of Y, Gd and Ce in an acid in stoichiometrical proportions, and coprecipitating the solution with oxalic acid. Oxide of the coprecipitation obtained by firing this material is mixed with aluminum oxide and gallium oxide, thereby to obtain respective mixture materials. The mixture is mixed with ammonium fluoride used as a flux, and fired in a crucible at a temperature of 1400 °C in air for 3 hours. Then the fired material is ground by a ball mill in water, washed, separated, dried and sieved thereby to obtain the desired material.

[0057]

40 Parts by weight of the first fluorescent material having a composition of $Y_3(Al_{0.5}Ga_{0.5})_5O_{12}$:Ce and capable of emitting green light, 40 parts by weight of the second fluorescent material having a composition of $(Y_{0.2}Gd_{0.8})_3Al_5O_{12}$:Ce and capable of emitting red light and 100 parts by weight of epoxy resin were sufficiently mixed to form a slurry. The slurry is poured into the cup which is provided on the mount lead wherein the LED chip is placed. Then the resin containing the fluorescent material is cured at 130 °C for 1 hour. Thus a coating layer containing the phosphor in thickness of 120 μm is formed on the LED chip. Concentration of the phosphor in the coating layer is increased gradually toward the LED chip. Further, the LED chip and the phosphor are molded with

translucent epoxy resin for the purpose of protection against extraneous stress, moisture and dust. A lead frame with the coating layer of phosphor formed thereon is placed in a bullet-shaped die and mixed with translucent epoxy resin and then cured at 150 °C for 5 hours. Under visual observation of the light emitting diode formed as described above in the direction normal to the light emitting plane, it was found that the central portion was rendered yellowish color due to the body color of the phosphor.

[0058]

Measurements of chromaticity point, color temperature and color rendering index of the light emitting diode which was obtained as described above and capable of emitting white light gave values of (0.32, 0.34) for chromaticity point (x, y), color temperature of 6000 K, 72 for Ra (color rendering index) and light emitting efficiency of 101 m/W. Further in weatherability tests under conditions of energization with a current of 60 mA at room temperature, 20 mA at room temperature and 20 mA at 60 °C with 90% RH, no change due to the phosphor was observed, showing no difference from an ordinary blue light emitting diode in the service life characteristic.

[0059]

[Effect of the Invention]

According to the present invention, by using a high-output light emitting component of nitride compound semiconductor and phosphors capable of emitting red light and green light , a light

emitting device which maintains a high light emitting efficiency over a long period of operation with a high can be made. With high reliability, energy saving performance, compact construction and capability to change color temperature, the present invention can open up new applications containing display and illumination in automobile, aircraft and electric appliances in general, as well as outdoor use such as buoys for harbors and ports and sign and illumination for expressways. Also the light emitting diode of the present invention is better for the human eyes because white light imposes less stimulation to the eye when watched for a long period of time.

[0060]

The construction described in claim 1 of the present invention, in particular, makes it possible to obtain a light emitting device capable of emitting white light having RGB components with high luminance, with minimum color shift and deterioration in light emission efficiency, even when used over an extended period of time.

[0061]

By making the light emitting device in the construction as described in claim 2 of the present invention, it is made possible to emit desired light which is closer to daylight color with minimum color shift and minimum deterioration in light emission efficiency, even when used over an extended period of time.

[0062]

By making the light emitting device in the construction as described in claim 3 of the present invention, it is made possible to emit white light in a planar construction with minimum color shift and minimum deterioration in light emission efficiency, even when used over an extended period of time.

[0063]

By making the light emitting device in the construction as described in claim 4 of the present invention, it is made possible to emit white light more uniformly in a planar construction with minimum color shift and minimum deterioration in light emission efficiency, even when used over an extended period of time.

[0064]

By making the light emitting diode in the construction as described in claim 5 of the present invention, it is made possible to emit white light containing RGB components with high luminance, with minimum color shift and minimum deterioration in light emission efficiency, even when used over an extended period of time under outdoor environment.

[0065]

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 is a schematic sectional view of the light emitting device of the present invention.

[Fig. 2] Fig. 2 is a schematic sectional view of the planar light source which is another light emitting device of the present invention, while (A) showing the planar light source having the

phosphor between the optical guide plate and the light emitting diode, and (B) showing the planar light source having the phosphor on the principal plane of the optical guide plate.

[Fig. 3] Fig. 3 is a schematic sectional view of the light emitting diode which is another light emitting device of the present invention.

[Fig. 4] Fig. 4(A) shows an example of absorption spectrum of the first and the second phosphors used in the present invention, and Fig. 4(B) shows an example of emission spectrum of the first and the second phosphors used in the present invention.

[Fig. 5] Fig. 5 shows an example of emission spectrum of the light emitting component used in the present invention.

[Fig. 6] Fig. 6 shows the results of weatherability test for the comparison of the present invention with the reference light emitting device, while (A) shows a relation between the luminance retaining ratio and the time, and (B) is a graph showing a relation between the color tone and the time.

[Fig. 7] Fig. 7 shows the results of reliability test for the comparison of the present invention with the reference light emitting device, while (A) shows a relation between the luminance retaining ratio and the time, and (B) is a graph showing a relation between the color tone and the time.

[Description of the Reference Numerals]

101, 210: Molding material wherein the phosphor is contained

102, 202, 302: LED chip

103, 303: Conductive wire

104: Casing

105: External electrode

201: Color conversion material

203: Substrate

204: Optical guide plate

205, 207: Reflective material

206: Diffusion sheet

301: Coating material wherein phosphor is contained

304: Molding material

305: Mount lead

306: Inner lead

Fig. 1

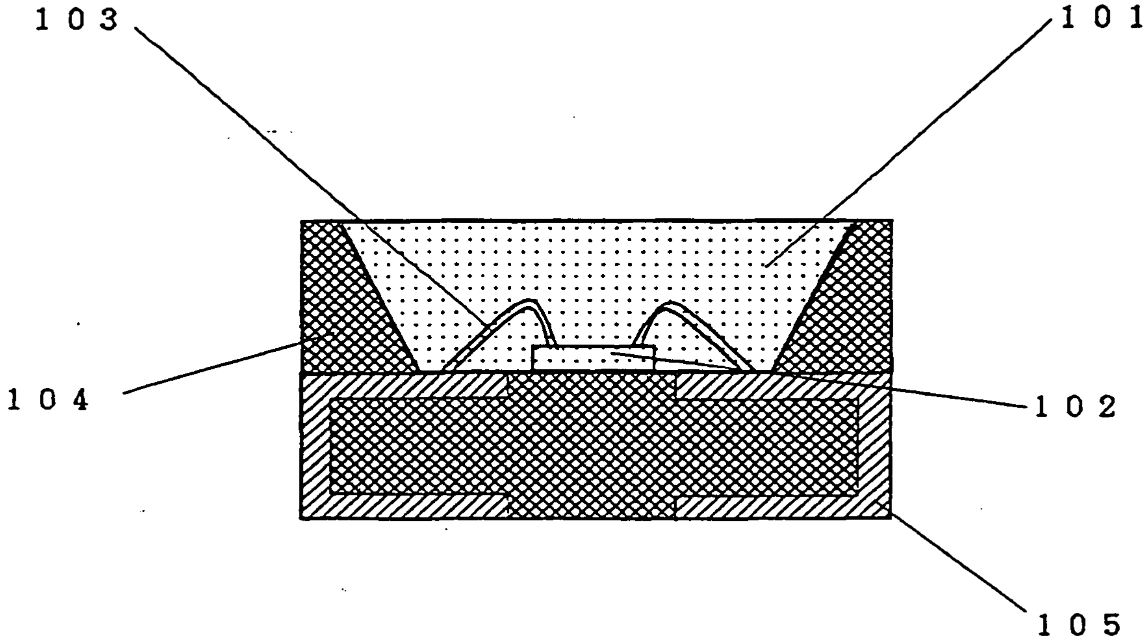
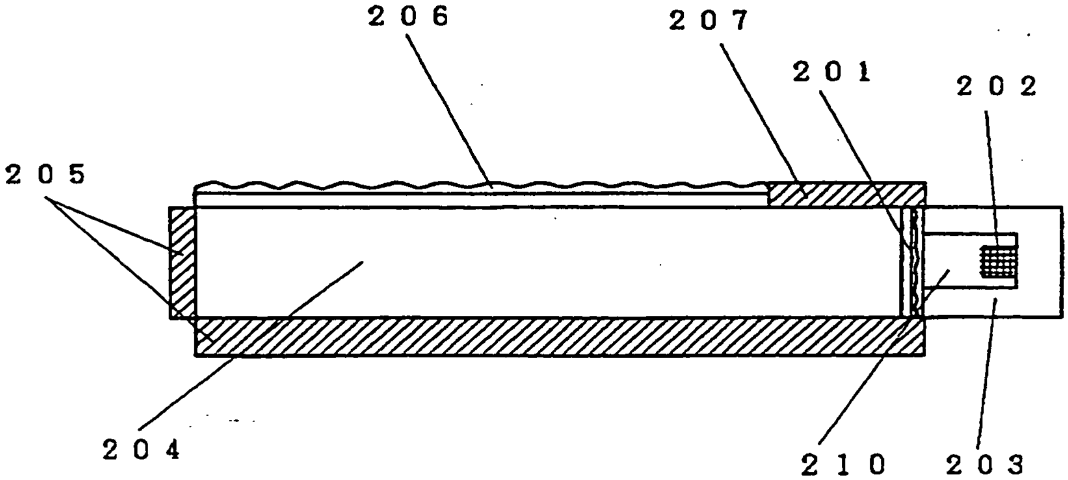
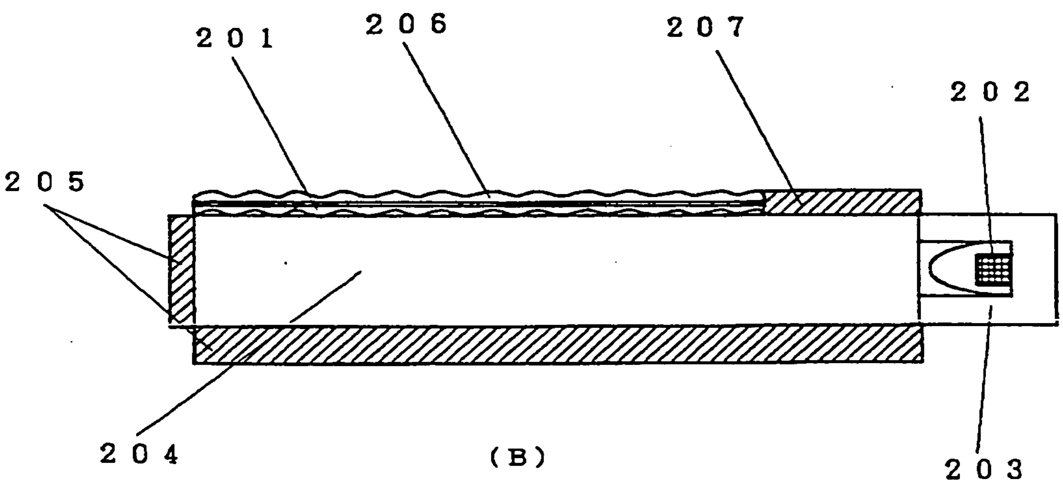


Fig. 2



(A)



(B)

Fig. 3

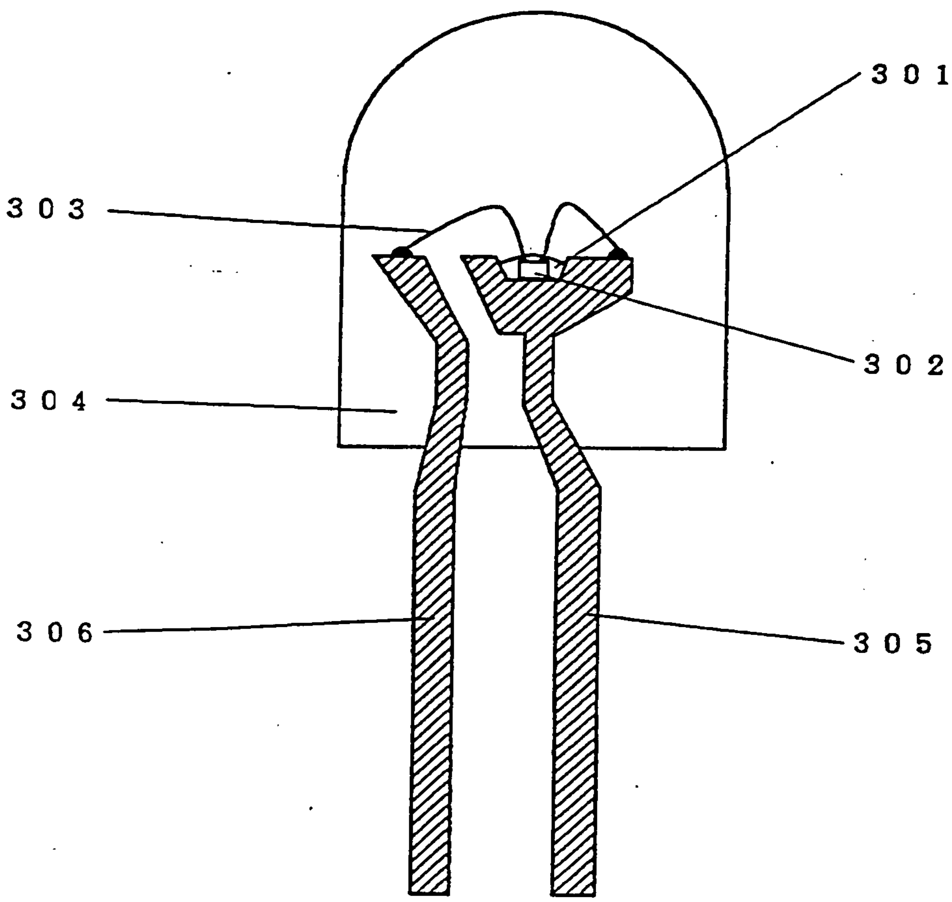
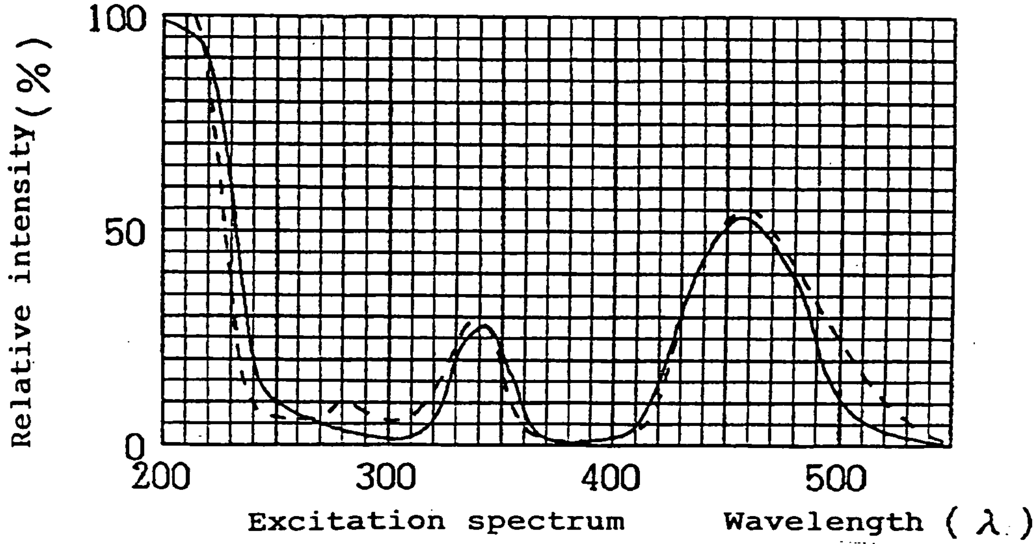
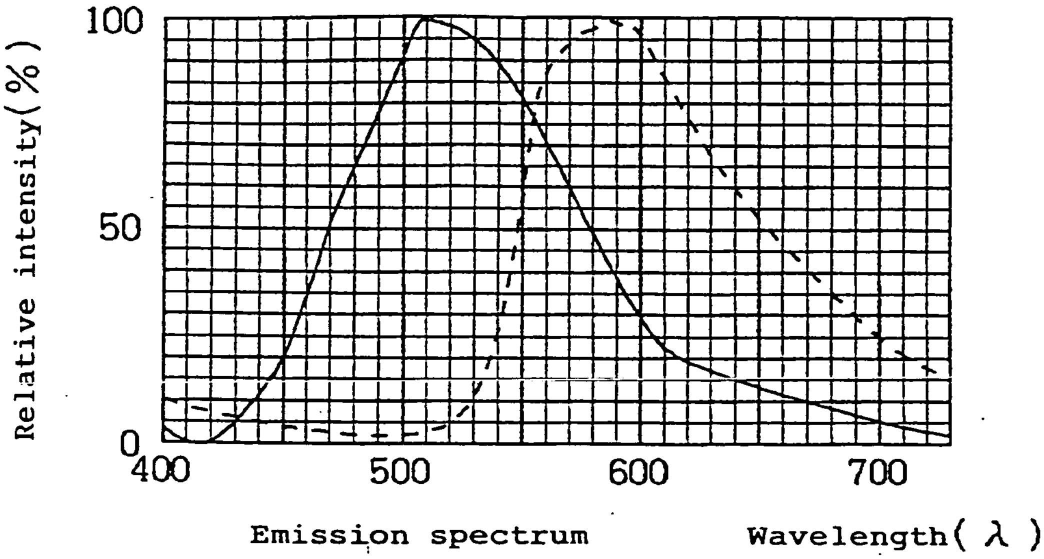


Fig. 4



100
50
0
Relative intensity (%)
200
300
400
500
Excitation spectrum
Wavelength (λ)

(A)



100
50
0
Relative intensity (%)
400
500
600
700
Emission spectrum
Wavelength (λ)

(B)

Fig. 5

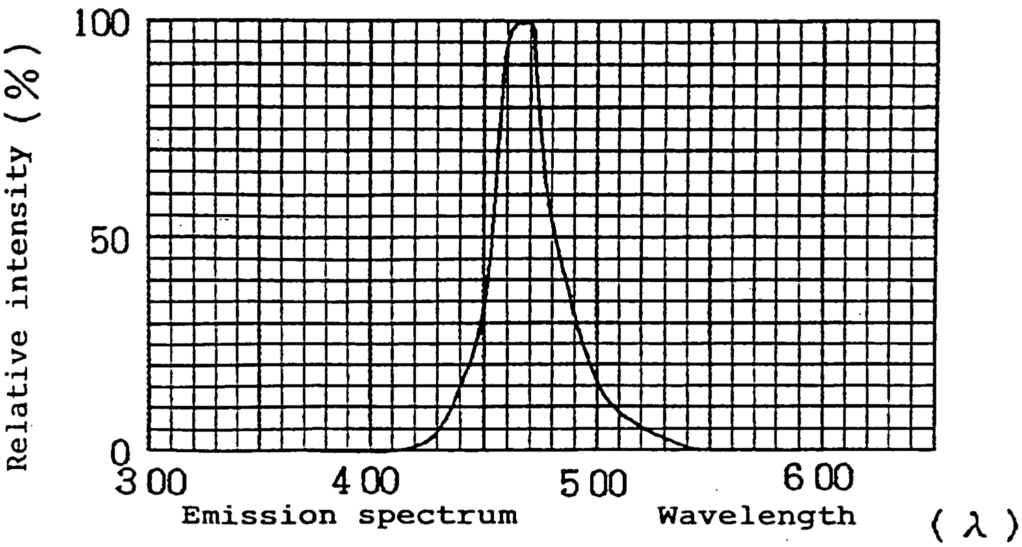
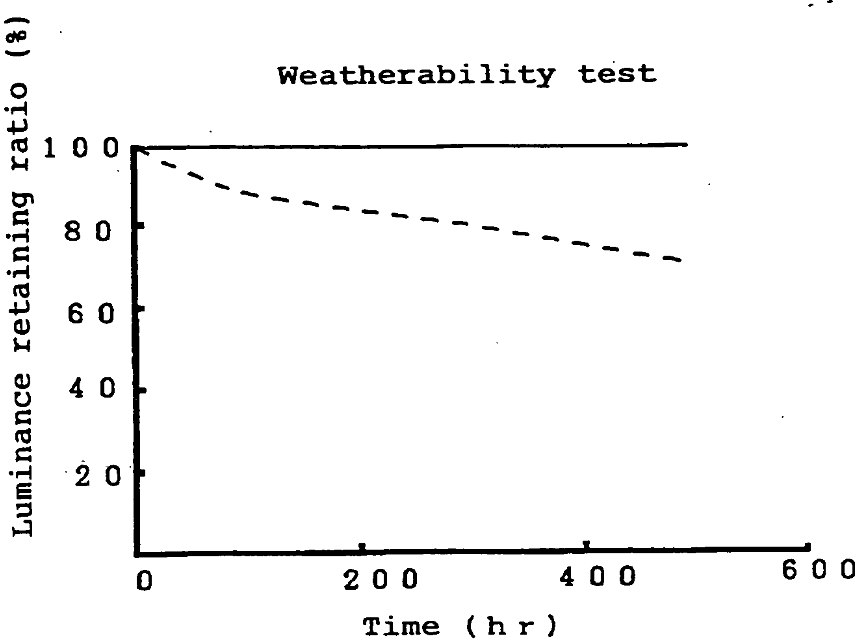
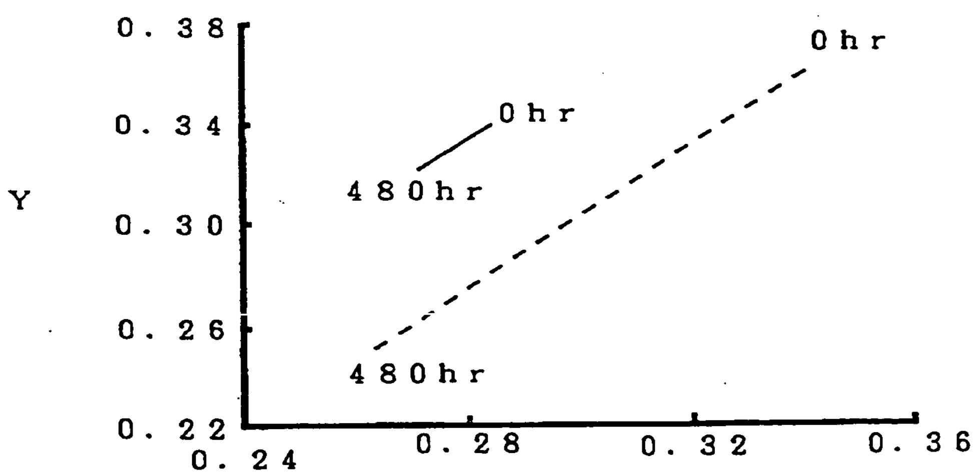

100
50
0
Relative intensity (%)
300
400
500
600
Emission spectrum
Wavelength
(λ)

Fig. 6



Weatherability test
Luminance retaining ratio (%)
100
80
60
40
20
0
200
400
600
Time (hr)

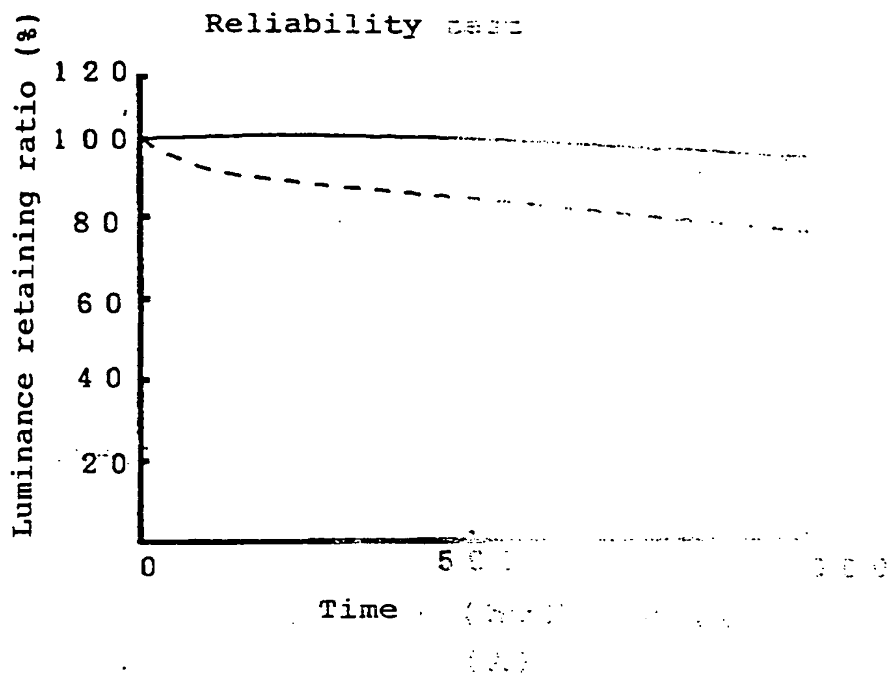
(A)



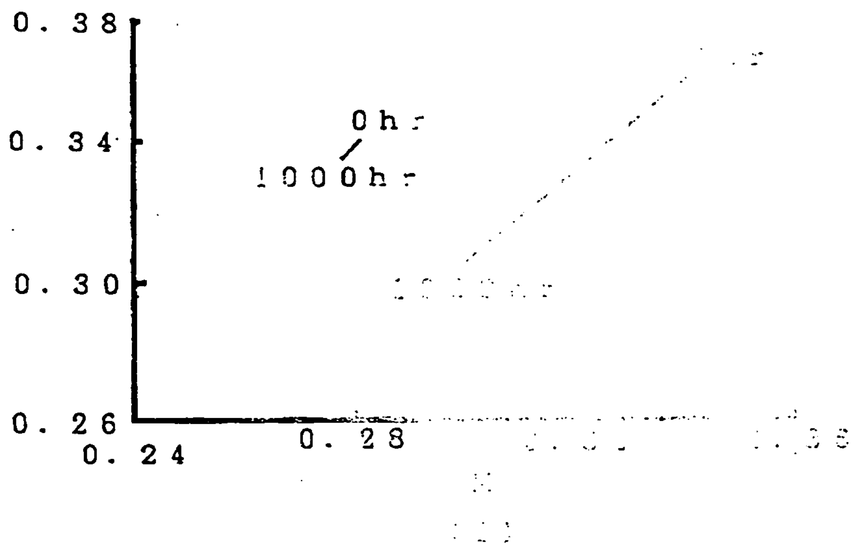
0.38
0.34
0.30
0.26
0.22
Y
0hr
0hr
480hr
480hr
0.24
0.28
0.32
0.36
X

(B)

Fig.7



Reliability
Luminance retaining ratio (%)
120
100
80
60
40
20
0
Time



0.38
0.34
0.30
0.26
0.24
0.28
0hr
1000hr

[Document Name] Abstract

[Abstract]

[Object] It is to provide a light emitting device which emits light of RGB (red, green, blue) colors with high luminance and high efficiency regardless of the operating environment, and a display device using the same.

[Means for solving] The light emitting device has a LED chip using a gallium nitride compound semiconductor as a light emitting layer and a phosphor which absorbs at least a part of light emitted by the LED chip to emit light by converting the wavelength. A main peak of the emission spectrum of the LED chip has an emission wavelength within the range from 400nm to 530nm and the phosphor contains a first fluorescent material represented by general formula $Y_3(Al,Ga)_5O_{12}$:Ce and a second fluorescent material represented by general formula $Re_3Al_5O_{12}$:Ce having a main emission wavelength longer than that of the first fluorescent material, where Re is at least one selected from Y, Gd and La.

[Selected drawing] Fig. 1

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Corrected Document: Petition for Patent

Approved or Supplemented Data:

Applicant:

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Applicant Record

Identification No.: [000226057]

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